Physics 222 Problem Set #2

(by Kelly Junge)

Ch. 19: Q13, (Q24), (P21), P22

Q13: It is found that charged particles from outer space, called cosmic rays, strike the Earth more frequently at the poles than at the equator. Why?

Solution: The charged particles heading toward Earth experience a magnetic force $\vec{F} = q\vec{v} \times \vec{B} = qvB \sin\theta$.

This magnetic force, acting perpendicular to the velocity of the particles, deflects them off course, possibly avoiding Earth. The magnetic force is minimized at the poles because the angle between the velocity (v) and the magnetic field (B) is small. The particles near the poles experience a smaller force than the particles near the equator. Therefore, more cosmic rays hit the Earth at the poles than at the equator.

Q24: The electron beam in Figure 19.29 is projected to the right. The beam deflects downward in a 0.001 T magnetic field that is produced by a pair of current-carrying coils. (a) What is the direction of the magnetic field? (b) If the diameter of the sphere is 0.1 m, estimate the speed of the electrons in the beam.

Solution: (a) The directions of the force and the velocity are given. Using the right hand rule and remembering that the charge of the electron is negative requires the magnetic field to be into the page. (b) Summing the forces in the y direction yields an expression for the downward acceleration.

$$\vec{a} = \frac{\vec{F}}{m_e} = \frac{-e\vec{v} \times \vec{B}}{m_e}. \qquad a = \frac{-evB}{m_e}.$$

The amount of time the electron is in the sphere is $t = \frac{d}{v} = \frac{0.1m}{v}$.

The equation for the height (y-direction) of the electron is $y = y_o + \frac{1}{2}at^2$. Substituting in for the acceleration and time;

then solving for the velocity (v) yields $v = \frac{1}{2}\frac{-eBd^2}{m_e(y - y_o)}$.

Assuming the change in y is -0.03m and putting in the numbers the velocity of the electron is approximately

$\boxed{v = 3\times 10^7 m/s}$.

P21: A rectangular loop consists of 100 closely wrapped turns and has the dimensions 0.4m*0.3m. The loop is hinged along the y axis, and the plane of the coil makes an angle of 30° with the x axis (Fig. 19.35). What is the magnitude of the torque exerted on the loop by a uniform magnetic field of 0.8 T, directed along the x axis, when the current in the windings has a value of 1.2 A in the direction shown? What is the expected direction of rotation of the loop?

Solution: Torque is dependent on: the number of turns (N), the current (I), the area of the loop (A), and the magnetic field (B).

$$\vec{\tau} = NI\vec{A} \times \vec{B}. \qquad = NIABsin$$

The plane of the loop is 30° from the x axis; therefore, the normal of the loop is 60° from the x axis. Theta (θ) is the angle between the magnetic field and the normal of the loop.

$$= (100)(1.2A)(0.4m \times 0.3m)(0.8T)\sin 60°$$
$$\boxed{= 9.98 \ N \cdot m}$$

The torque will rotate the loop to the z axis (τ=0 at z axis). This rotation aligns the magnetic moment of the loop and the magnetic field.

P22: A small bar magnet is suspended in a uniform 0.25 T magnetic field. The maximum torque experienced by the bar magnet is 4.6×10^{-3} Nm. Calculate the magnetic moment of the bar.

Solution: The maximum torque occurs when the angle between the magnetic moment and the magnetic field must be 90°. The torque equation thus reduces to

$$= \ B.$$

Solving for the magnetic moment (μ) and plugging in the numbers yields

$$= \frac{}{B} = \frac{4.6 \times 10^{-3} \ N \cdot m}{0.25 \, T} = \boxed{1.84 \times 10^{-2} \, Am^2}$$

Note: Question 24 and Problem 21 are also solved in the Student Solutions Manual.